Emission Reductions from the U-Pass Program in the Georgia Basin

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ABSTRACT

Greenhouse gases (GHG) and criteria air contaminants (CAC) are of increasing concern because of their contribution to climate change and detrimental effects on human and environmental health, respectively. In the Georgia Basin, a major source of GHGs and CACs is transportation, which is continually increasing due to population and economic growth in the region. To meet this transportation demand and to reduce air emissions, the universal bus pass (U-Pass) program has been implemented at the University of British Columbia (UBC) and the University of Victoria (UVic). This study quantifies the air emissions reductions achieved and determines the effectiveness of the program from an air emission standpoint. The methodology is largely based on the framework developed by UBC Masters student Jonathan Frantz, who modeled GHG emissions from mobile sources before and after the implementation of the U-Pass program at UBC. For the purposes of this study, Frantz's framework has been modified and applied to up-to-date information from UVic and UBC; the methodology has been further extended to include CACs (CO, NOx, VOC, PM, SOx, NH_3). This study indicates that UBC has reduced approximately 8000 tonnes of carbon dioxide equivalents (CO_2e) and 10-15% of CAC emissions in 2003/2004. UVic will have reduced nearly 3000 tonnes of CO_2e and 15-19% of CAC emissions in 2004/2005. UBC and UVic's successful implementation of the U-Pass program could potentially encourage other educational institutions to adopt a similar program to reduce their air emissions.

INTRODUCTION

Greenhouse gases (GHG) and criteria air contaminants (CAC) are of increasing concern because of their contribution to climate change and detrimental effects on human health, respectively. In the Georgia Basin, a major source of GHGs and CACs is transportation, which is continually increasing due to population and economic growth in the region. To meet this transportation demand and to reduce air emissions, the universal bus pass (U-Pass) program has been established at the University of British Columbia (UBC) since 2003 and at the University of Victoria (UVic) since 1999. This study quantifies the air emission reductions achieved and determines the effectiveness of the program from an air emission and air quality standpoint. The methodology is based on the framework developed by UBC School of Community and Regional Masters student, Jonathan Frantz. In 2003 and 2004, Frantz modeled GHG emissions from mobile sources before and after the implementation of the U-Pass program at UBC. For the purposes of this study, Frantz's framework has been modified and applied to up-to-date information from UVic and UBC; the methodology has been further extended to include CACs. The GHGs examined are carbon dioxide (CO_2), methane, (CH_4) and nitrogen dioxide (NO_2); the CACs studied are carbon monoxide (CO), nitrous oxides (NOx), volatile organic compounds (VOC), inhalable particulate matter (particulate matter 10µm and smaller, PM10), respirable particulate matter (particulate matter 2.5µm and smaller, PM2.5), sulphur oxides (SOx), and ammonia (NH_3).

By quantifying the reductions in greenhouse gases, these universities may participate in International Emissions Trading (IET). IET is a market-based instrument where carbon credits can be bought and sold.[1] It is being used to help steer Canada towards meeting its commitment to the Kyoto Protocol, an international agreement requiring that greenhouse gases be reduced by pre-determined levels (Frantz, 2003). The universities are not yet participating in IET. However, GEMCo, a non-profit organization actively involved in reducing greenhouse gases, is just one of the organizations that are interested in buying carbon credits from UBC's U-Pass program (Frantz, 2003). This is an option that the University of Victoria may also want to consider.

Recommendations have also been made for further studies to be conducted at UBC and UVic to measure factors that have been ignored in this study due to limited information. In addition, it has been recommended that Simon Fraser University and Camosun College, two other institutions that have established the U-Pass program, conduct similar studies. They have not been included in this paper as detailed transportation data has not yet been collected by the institutions.

METHODOLOGY

The methodology is based on a framework developed by UBC Masters student Jonathan Frantz (2003 and 2004). Frantz developed this framework to estimate UBC's GHG emission reduction in 2003 as a consequence of the U-Pass program. However, the calculations did not account for changes to the vehicle profile and commuting population. In addition, two different sources of transportation data were used. This study has attempted to obtain a more accurate estimate of the GHG emission abatement by calculating two sets of emissions - with and without the U-Pass program - for a single year. It has used only one source of transportation data for each university and has included CAC emission reduction estimates. Calculations for UBC have been performed for the 2003/2004 academic year while emission estimates for UVic have been determined for the 2004/2005 academic year (summer semesters have been included in both academic years). These years have been selected based on data availability.

Below is an overview of the procedure used to estimate the emissions with the U-Pass program implemented. The same procedure has been used to model the theoretical emissions without the program. However, different values have been used for the following variables: the percentage of passengers traveling by vehicles and by buses; the average number of passengers per diesel bus; and the percentage of bus kilometres traveled by diesel buses. These values have been taken from a year before the establishment of the program.

1. Information provided by the universities has been used to determine the annual number of passenger one-way trips made to and from each institution.
2. The annual number of passenger one-way trips, the percentage of passengers commuting by each mode of transportation, and the number of passengers per vehicle or diesel bus (electric trolley buses are assumed to have insignificant tailpipe emissions) have been used to calculate the annual number of vehicle one-way trips made by each transportation mode.
3. The annual number of vehicle one-way trips made by each transportation mode has been multiplied by the average commuting distance to determine the total vehicle and bus kilometres traveled.
4. The total distances traveled by vehicles and by buses have been multiplied by their corresponding GHG and CAC emission factors (in units of grams of pollutant/vehicle kilometres traveled) to determine the total GHG and CAC emissions.

[1] To offset the emissions that are produced from one's activities, one can purchase carbon offsets. This money is invested into projects that reduce GHG emissions.

1. Calculating the Total Annual Number of Passenger One-way Trips

To determine the annual number of passenger one-way trips, three sets of information have been used:
a) annual number of fall equivalent working days for students and for faculty / staff (reflecting the number of days that students and faculty / staff are commuting to campus);
b) number of passenger one-way trips taken on a typical fall weekday;
c) and percentage of the commuting population that are students and that are faculty / staff.

The commuting population has been divided into students and faculty / staff as the annual number of fall equivalent working days are different for the two groups. The three sets of information mentioned above have been inserted into Equation 1 to calculate each group's annual number of passenger one-way trips. The results have been added together to obtain the total annual number of passenger one-way trips.

Equation 1: Annual number of Passenger One-way Trips for the Given Group

Annual number of working days for a given group	x	Total number of passenger one-way trips for all groups on a typical fall day	x	The given group's percentage of the total commuting population	=	Annual number of passenger one-way trips for the given group

For students, the annual number of fall equivalent working days has been determined using several assumptions made in Frantz's methodology:
a) summer student enrolment is approximately 22% of the fall session enrolment (i.e. regular class time);
b) during exam periods, students make 42% of the commutes that they make during regular class time;
c) and during reading weeks, students make 30% of the commutes that they make during regular class time.

According to Frantz and UVic's Sustainability Coordinator, UBC and UVic faculty / staff are assumed to have 240 and 260 working days respectively. However, the actual number of working days could vary over time with the increasing popularity of teleworking and an aging faculty and staff profile (Frantz, 2003).

The number of trips taken on a typical fall weekday has been estimated using count data collected at the institutions (Urban Systems, 2004 and Bunt and Associates, unpublished). For the purpose of this study, it is assumed that the count surveys only include students and faculty / staff who are traveling to and from home. Although students may commute to other locations, it is assumed that they will use the same mode of transportation to return to their residences. As the count results do not distinguish between students and faculty / staff, the population distribution has been determined by comparing the number of full-time equivalent students to full-time equivalent faculty / staff. This information has been recorded by UBC's Planning and Institutional Research office (Planning and Institutional Research, 2005) and UVic's Institutional Planning and Analysis office (Institutional Planning and Analysis, 2005). Students and faculty / staff living on campus are assumed to have full time status and have therefore been excluded from all calculations. Estimates of the on-campus population have been provided by UVic's Sustainability Coordinator (personal communication, November 29, 2004), the Assistant Director of UBC Housing (personal communication, October 18, 2004) and the Properties Administrator of UBC Properties (personal communication, October 18, 2004).

2. Calculating the Number of One-way Trips Made by Each Mode of Transportation

Information on vehicle occupancy and the percentage of passengers commuting by vehicles and by buses has been collected in count surveys before and after the implementation of the U-Pass. Information on the average number of passengers per diesel bus has been gathered by the Coast Mountain Bus Company for UBC (Long, R., personal communication, March 7, 2005) and Bunt and Associates for UVic (Webb, S., personal communication, January 28, 2005). All of this information has been inserted into Equation 2 to determine the number of one-way trips made by each mode of transportation.

Equation 2: Number of One-way Trips Made by Each Mode of Transportation

Total annual number of passenger one-way trips	x	Percentage of passengers traveling by each mode of transportation	x	1 / Number of passengers in each vehicle or bus each	=	Number of one-way trips made by mode of transportation

3. Calculating the Total Distance Traveled by Vehicles and by Buses

To estimate the total distance traveled by vehicles and by buses, Equation 3 has been used. The average commuting distances for both students and faculty / staff members are assumed to be 17.3 km at UBC (Frantz, 2003), and 10 km at UVic (Webb, S., personal communication, November 24, 2004). It is assumed that both vehicles and buses commute the same distance.

Equation 3: Total Kilometres Traveled by Each Mode of Transportation

Number of one-way trips made by each mode of transportation	x	Avg. commuting distance	=	Total kilometres traveled by each mode of transportation

As only diesel buses influence emissions in this study, the total bus kilometres traveled by diesel buses has been calculated. This has been determined by estimating the percentage of bus kilometres traveled by diesel buses versus trolley buses. This information has been supplied by Coast Mountain Bus Company and the Victoria Regional Transit System (UVic's transit provider).

4. Calculating Total GHG and CAC Emissions

The total kilometres traveled by each mode of transportation have been multiplied by the corresponding GHG and CAC emission factors obtained from a Greater Vancouver Regional District (GVRD) spreadsheet (unpublished) and a report by Levelton (unpublished). These emission factors were calculated using the GVRD vehicle profile, TransLink's (Vancouver's transit provider) bus fleet profile, and two versions of the emission factor calculator Mobile 6. Mobile 6.2 (the American version) was used to calculate the TransLink emission factors while Mobile 6.2C (the Canadian version) was used to obtain the vehicle emission factors. The two different versions were used as the calculations were completed at separate times and by different agencies. However, both of these calculators generally produce similar results. The greenhouse gas emission results have been expressed in carbon dioxide equivalents (CO_2e) by multiplying the emission values by their global warming potential (a measure of a pollutant's potency relative to carbon dioxide).

For the purpose of this study, it is assumed that UBC and UVic's vehicle and bus profiles are identical to the GVRD profiles. In addition, it is assumed that 77% of the vehicles are light-duty gas vehicles and

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the remaining 23% are light-duty gas trucks (Frantz, 2003). A survey completed at UBC has confirmed that this is a reasonable assumption for this particular institution's vehicle fleet (Frantz, 2003). However, the buses operating at UBC may be newer than the general TransLink bus fleet. Therefore, the actual bus emissions may be lower and the overall emission reductions may be larger. UVic's actual NOx, VOC, and CO emissions may also be higher than the GVRD fleet. This is due to the absence of the AirCare Program in Victoria. The AirCare Inspection and Maintenance Program and On-road Program, present in the Lower Fraser Valley, have been reported to reduce NOx, VOC, and CO emissions by approximately 11.0%, 25.0%, and 24.0% respectively for light-duty vehicles and 0.5%, 1.9%, and 0% respectively for heavy-duty vehicles (e.g. diesel buses) (Levelton, 2004). Thus, UVic's actual NOx, VOC, and CO emission reductions may be different than the results of this study. The NOx and CH_4 emission factors for buses are also assumed to have remained unchanged from 1999-2005 (GVRD, personal communication, February 1, 2005).

RESULTS AND DISCUSSION

This study indicates that the U-Pass has significantly reduced GHG and CAC emissions at both UBC and UVic. Table 1 summarizes the emission reduction results for UBC in 2003/2004. UBC reduced approximately 8000 tonnes of CO_2e that year. This is a 13.7% reduction in CO_2e. Similarly, all of the measured CAC emissions have been significantly reduced. CO, NOx, SOx, VOC, and NH_3 have been reduced by 12.5-14.8%. The reductions in PM10 and PM2.5 have been slightly lower – 11.6% and 10.1% respectively. This is likely due to diesel engines (which are used by buses) having higher PM emissions relative to regular gasoline-run automobile engines.

Table 1: UBC Transportation CO_2e and CAC Emissions With and Without the U-Pass Program (2003/2004)

Pollutants (tonnes)	Without U-Pass	With U-Pass	Net Change	Percent Reduction
Total CO_2e	58,271	50,301	-7,969.91	13.7%
Per capita CO_2e	1.64	1.41	-0.19	13.7%
CO	2476	2110	-366	14.8%
NOx	207	181	-26.0	12.5%
PM10	4.32	3.82	-0.50	11.6%
PM2.5	2.63	2.36	-0.26	10.1%
SOx	4.23	3.71	-0.52	12.3%
VOC	214	182	-32	14.8%
NH_3	11.68	9.95	-1.73	14.8%

These significant emission reductions are mainly due to a shift in the transportation patterns of the university's commuting population. As Figure 1 indicates, the percentage of passenger trips being made in SOV's and HOV's in 2003/2004 have decreased from 43 to 39% and 26 to 19% respectively, while transit ridership has increased from 27 to 39%.

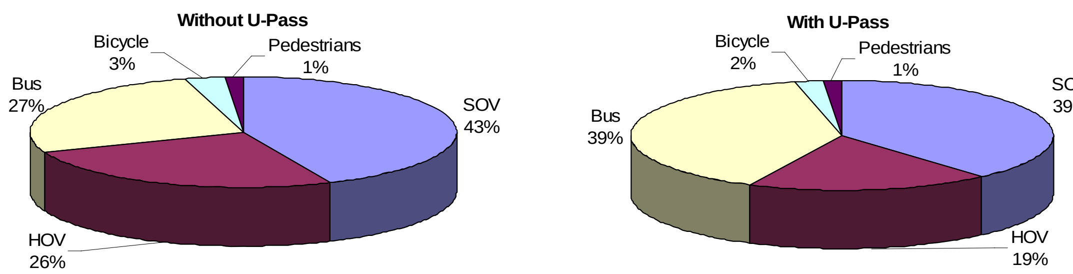

Figure 1: UBC Transportation Patterns With and Without the U-Pass Program (2003/2004)

UBC's GHG reduction calculated in this study is notably lower than the value calculated by Frantz (2004). This is mainly due to a difference in the methodology used to calculate the total distance driven by vehicles and by buses. Whereas Frantz has used two different sources of transportation data to calculate the distance driven before and after the establishment of the U-Pass Program, this study has only used transportation data collected from count surveys (Urban Systems, 2004).

Since the U-Pass has been established, UVic has experienced a similar shift in transportation patterns. During the 2004/2005 academic year, it is predicted that SOV and HOV passenger trips will have decreased from 44 to 36% and 29 to 23%, respectively (Figure 2). Bus ridership will have increased from 11 to 26%. As Table 2 indicates, these changes will have led to an 18.3% reduction in CO_2e, which is equivalent to nearly 3000 tonnes of CO_2e being abated. Similarly, all of the measured CAC emissions will have been significantly reduced. CO, NOx, SOx, VOC, and NH_3 will have been reduced by 17.0-19.3% while PM10 and PM2.5 will have been reduced by 16.5 and 15.0% respectively.

Table 2: UVic Transportation CO2e and CAC Emissions With and Without the U-Pass Program (2004/2005)

Pollutants (tonnes)	Without U-Pass	With U-Pass	Net Change	Percent Reduction
Total CO_2e	16,133	13,185	-2948	18.3%
Per capita CO_2e	1.06	0.87	-0.41	18.3%
CO	702	567	-136	19.3%
NOx	55.7	46.1	-9.6	17.2%
PM10	1.12	0.94	-0.19	16.5%
PM2.5	0.65	0.55	-0.10	15.0%
SOx	1.14	0.94	-0.20	17.0%
VOC	60.5	48.8	-11.7	19.3%
NH_3	3.31	2.67	-0.64	19.3%

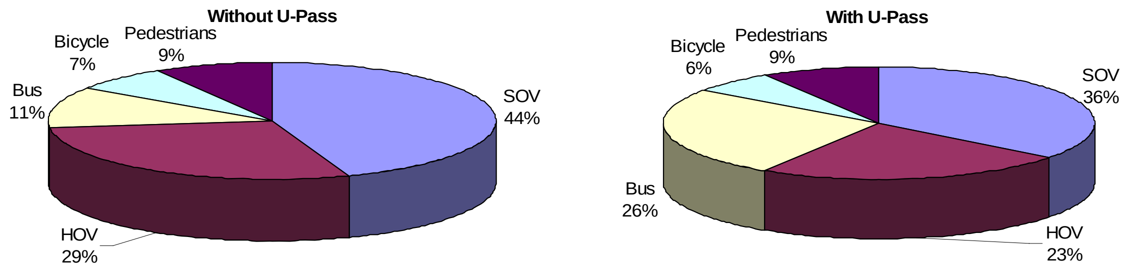

Figure 2: UVic Transportation Patterns With and Without the U-Pass Program (2004/2005)

These large GHG and CAC emission reductions may benefit human and environmental health. The abatement in greenhouse gases may reduce the universities' contribution to climate change, while the reductions in common air contaminants may decrease ambient CAC levels. Thus, human exposure to these pollutants may decrease and so may the accompanying risk of cardiovascular and respiratory diseases.

These GHG reductions may also be sold as carbon credits. With the results of this study, UBC and UVic may now approach interested organizations such as GEMCo (a Canadian non-profit organization that is developing voluntary and market-based approaches to help manage GHG emissions) with an estimate of their emission reductions and be actively involved in carbon trading.

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RECOMMENDATIONS AND OTHER CONSIDERATIONS

Indirect effects of the U-Pass Program

In addition to reducing air pollution, the U-Pass has many other benefits. A recent TransLink survey (TransLink, 2004) has found that UBC's U-Pass has increased students' options on where to live, work, and shop. Students have also been less reliant on automobiles, including on non-school trips. According to the survey, 37% of UBC's students have avoided purchasing a vehicle as a result of the U-Pass (TransLink, 2004). The increased transit ridership also helps sustain a strong public transit system. This benefits university students, transit agencies, and other transit customers.

Recommendations to Further Reduce PM and Other Air Emissions

While the U-Pass program has reduced overall PM emissions from the transportation sector, total PM emitted from diesel fuel has increased as more bus trips are being made. This is a concern as some studies have reported PM emissions from diesel fuel to be carcinogenic (i.e. worse than gasoline PM). TransLink and BC Transit should therefore consider options to reduce tailpipe emissions from buses. This could be accomplished by increasing the percentage of bus trips made by electric trolley buses, which are assumed to have insignificant tailpipe emissions. Another option would be to retrofit diesel buses with technologies such as diesel oxidation catalysts (DOCs) or diesel particulate filters (DPFs) [2]. These technologies reduce PM emissions by 20-50% (NWAPA, 2002) and 80-90% (Washington State University Extension Energy Program, n.d.), respectively. TransLink and BC Transit have retrofitted 37 diesel buses with DOCs under the Canadian Urban Transportation Authority national urban transit bus retrofit program (CUTA, n.d.). Still, there are many more buses within the fleet that could be retrofitted. Any of these emission reduction technologies would involve additional costs.

Additional Studies

For the purpose of this study, it is assumed that the count surveys only include students and faculty / staff that live off-campus. However, visitors and travelers that live on-campus may also have been included in the surveys. Therefore, it is recommended that future count surveys make a distinction between visitors and non-visitors and between travelers who live on- and off-campus. Information on the distances traveled by visitors and passengers that live on-campus should also be collected.

To obtain more accurate estimates of UVic's transportation emissions, emission factors specific to UVic's vehicle and bus fleets also need to be developed. In this study, UVic's vehicle and bus profiles are assumed to be similar to the GVRD profiles. However, this may be an incorrect assumption as the GVRD's vehicle inspection program is absent in Victoria.

The U-Pass program has also been established at Simon Fraser University and Camosun College. They have not been included in this study as detailed transportation data have not yet been collected. It is recommended that these institutions conduct count surveys similar to those that have been performed at UBC and UVic. This would enable them to quantify their emission reductions.

CONCLUSION

[2] Diesel particulate filters must be used in conjunction with ultra-low sulphur diesel.

The success of the U-Pass program is not only seen in the reduction of vehicle use. As this study has proven, air emissions have also been dramatically abated. If other educational institutions are interested in reducing their air emissions, they should consider implementing the U-Pass program. Support for such programs from students may likely exist as U-Passes tend to be much lower in cost than regular bus passes. Transit systems may also support this program as it increases public transit ridership and revenues. Interested institutions could start exploring the viability of such a program with their public transit systems and then begin surveying students, faculty, and staff. Simultaneously, they could raise awareness of the program and its benefits. To track their emission reductions, institutions could conduct consistent transportation surveys before and after implementing the program. This could help them quantify their emission reductions and allow them to participate in International Emissions Trading.

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